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Energy Trends and Implications for U.S. Army Installations

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Introduction

The energy situation is highly uncertain–for the Army, the Nation, and the world. Now is the time to consider both short and long-term issues to develop enduring energy policies and solutions for our military installations to discern an effective and viable path for the Army's energy future. To sustain its mission and ensure the capability to project and support the forces, the Army must insulate itself from the economic and logistical energy-related problems coming in the near- to mid-future. This requires a transition to modern, secure, and efficient energy systems and to building safe, environmentally friendly technologies. This is both a supply-side and demand-side challenge requiring integrated solutions and thoughtful planning and execution.

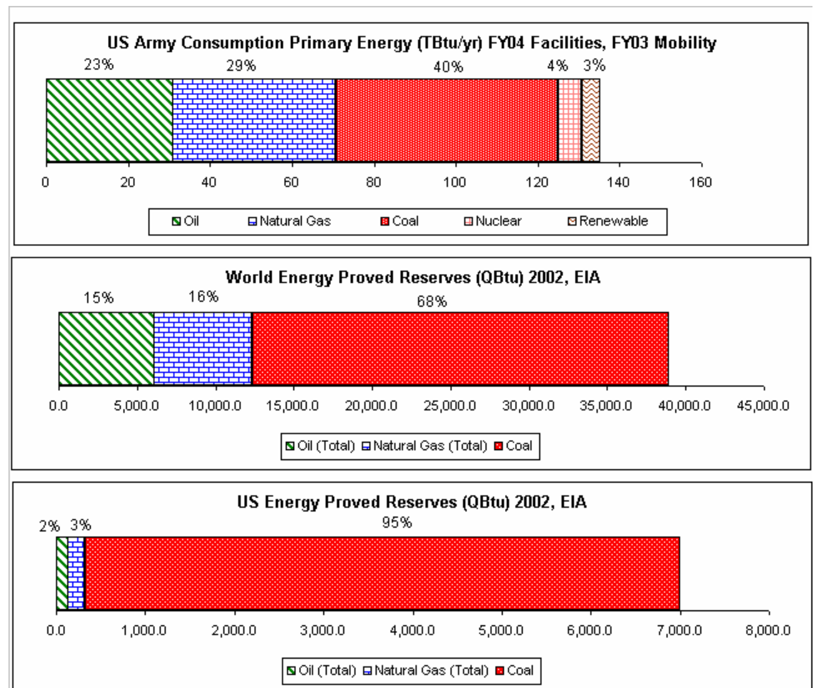

Figure 1. Army energy consumption in relation to resources.

Issues

Primary issues affecting energy options are: availability, affordability, sustainability, and security. Any review of these issues must take a global perspective since resources are unevenly distributed around the world. Further, the impacts of energy consumption have global reach from both an environmental and political perspective.

Energy Trends

Figure 1 and Table 1 show current demand, supply, and proportionate distribution of energy for the world, nation, and Army. Table 2 lists world reserves. The Army and the nation's heavy use of oil and natural gas is not "in synch" with the nation's or the earth's supplies. The relative fuel shares of energy use vs. energy reserves underscores our need to supplement oil and natural gas as our staple fuels. The domestic supply and demand imbalance would lessen if coal and/or nuclear energy were made more environmentally acceptable or if the renewable share of our energy portfolio were to increase.

Worldwide energy consumption is expected to increase by 2.1 percent/yr and domestic energy consumption by 1.4 percent per year. This will exacerbate global energy competition for existing supplies. Army energy consumption is dominated by facilities consumption. Facilities consumption may decrease in both total quantity and in intensity basis—but not without an aggressive energy program with careful planning, diligent monitoring, and prudent investment. The closure of European installations and relocation of troops onto domestic installations will make this outcome especially challenging. The energy consumption associated with Army mobility (tactical and nontactical vehicle consumption) is expected to remain constant, but may potentially increase depending of future phases of the Global War on Terror and on geopolitical tensions resulting from the world energy situation.

Natural Gas Trends

The natural gas market for the near and mid-term is expected to be volatile. Prices will fluctuate significantly based on weather and supply. In the near term, prices will increase continually until the natural gas market is normalized by constructing a gas pipeline from Alaska and northern Canada, by expanding exploration and production to areas of the United States now off limits, and by greatly increasing imports of liquefied natural gas.

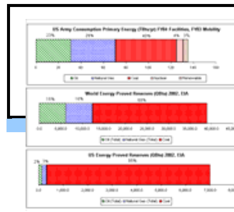

Table 1. Summary of U. S. and world energy consumption.

	Oil	Natural Gas	Coal	Nuclear	Renewable	Electricity	Purchased Steam	Total
Fuel Share of U.S. consumption	40%	23%	23%	8%	6%			100%
U.S. consumption (Q/yr) 2003, EIA	39	23		8	6			98
U.S. Imports (Q/yr)	22	4						26
U.S. imported share	56%	17%						26%
World consumption (Q/yr) 2003, BP renewables, EIA, 2002	147	94	104	24	32			401
U.S. consumed share of world consumption	27%	24%	22%	32%	18%			24%
U.S. Army end use consumption (TBtu/yr), Annual Reports, FY04 facilites, FY03 mobility	29	26	7		1	30	7	100
End use fuel share of Army consumption	29%	26%	8%	0%	1%	30%	7%	100%
U.S. Army consumption primary fuels (TBtu/yr) FY04 facilities, FY03 mobility, EIA 2003 generation mix	31	40	54	6	4			135
Primary fuel share of Army consumption	23%	29%	40%	4%	3%			100%

Table 2. Summary of U.S. and world energy reserves.

	Oil	Natural Gas	Coal	Nuclear	Renewable	Total
U.S.proved reserves (Q) 2002, EIA	132	193	6,678			7,003
Domestic proportion fossil fuel	2%	3%	95%			
World proved reserves (Q) 2002, EIA	6,027	6,317	2,6578			38,921
World proportion fossil fuel	15%	16%	68%			

The world market for natural gas is limited by demand, not supply. (World production capacity currently exceeds supply.) However, domestic natural gas production plateaued in 1973 and the United States currently imports 17 percent of the natural gas it consumes. This imported share will increase dramatically in the long term as domestic supplies deplete and the amount of natural gas used to fuel the electric system increases. In about 10 years, world natural gas markets will reach equilibrium on supply/cost basis, but at higher prices reflecting the higher costs of production and transportation. In the long run, worldwide natural gas production will peak in the 2030-2035 time range and then decline as an available resource.

Petroleum Trends

The supply of oil will remain fairly stable in the very near term, but oil prices will steadily increase as world production approaches its peak. The doubling of oil prices in the past couple of years is not an anomaly, but a picture of the future. Peak oil is at hand with low availability growth for the next 5 to 10 years. Once worldwide petroleum production peaks, geopolitics and market economics will result in even more significant price increases and security risks. To guess where this is all going to take us is would be too speculative. Oil wars are certainly not out of the question. Disruption of world oil markets may also affect world natural gas markets as much of the natural gas reserves are collocated with the oil reserves.

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Table 3. Energy options.

	Fossil fuels						
	Conventional Oil	Nat Gas Liquids, Deep Water, and Polar Oil	Unconventional Oil - Natural Bitumen (tar sands and extra-heavy crude)	Unconventional Oil - Oil shale	Natural Gas	Liquefied Natural Gas	Coal
Current price	$70/Barrel (WTI-world price)	World oil price	World oil price	Oil shale not economically viable	$6-7/MBtu wholesale at Henry Hub	$4.77/MBtu	$28.62/ton steam coal
Projected price trend	Steady increases expected as world production at or near peak (high was in 1973 @ $75/b in today's dollars).	NA	NA	Unknown	Volatile near term. Stable as LNG imports increase and AK pipeline built. Realistic floor is about $7/mbtu.	Price levels should sustain in the $3-4 dollar range until depletion sets in.	Fairly stable, but will tend to follow other fuels in an upward trend.
World production	25GB/yr	3.6GB/yr	0.25GB/yr	351 metric tons oil/yr	95 TCF	5.9 TCF	104 Quadrillion Btu
Demand expectations	Up 33% worldwide 2004-2020, 2.1%/yr	Part of conventional demand.	Will have to make up increasing portion of oil supply in the future.	If economically and environmentally viable, demand would take all that could be produced.	Up 50% in U.S. 2002-2022 Est. 2.5%/yr growth in U.S.	2 BCF/day, 3% of NG total in U.S., expected to expand rapidly as domestic NG production drops and world market develops, could eventually make up 33-50% of U.S. supplies.	Estimated at 1.5%/yr
Advantages	High energy density, easy to extract, transport and store, highly versatile for technologies, burns at high temp (suitable for IC engines)	High energy density, highly versatile for technologies, burns at high temp (suitable for IC engines)	Can be processed to conventional oil substitute.	Can be processed to conventional oil substitute.	Clean burning with low emissions, supplied by an extensive grid, can be used in a variety of equipment and substitute for petroleum in most cases.	Can be imported to make up for domestic shortage.	High specific energy density, readily available domestic supply, relatively low cost.
Disadvantages	Heavy dependence drives U.S. general economy. Increases reliance on foreign sources. Depletion causes price increases, could lead to disruption and geopolitical instability.	Deep water and polar oil are expensive to develop and limited in extent.	Deposits are mostly located in two countries: tar sands in Canada and extra-heavy crude in Venezuela.	Oil shale and tar sands energy ROI is negative, significant environmental impact	Demand exceeds domestic supply, decline rate about 30%, price volatility,	Infrastructure not ready, 7+yr lead time, high demand in the world market, supply terminals and ships must be expanded to meet demand, 33% energy loss in production.	High emissions. Mining is dangerous, destroys environment and pollutes surface and groundwater. Produces more CO_2 than other fossil fuels.
Domestic availability	Peaked in 1970. U.S. imports 62% of crude oil. Proved reserves are 132Q.	NA	NA	Est. 500Bbl from oil shale in U.S.	Peaked in 1973, plateaued since 1980 due to massive exploration. U.S. has 4% of world reserves. Proved reserves are 193Q.	None, this is an import fuel.	High
Domestic Proved Reserve Life (R/C ratio) if no incr. demand	3.4yrs			500 GB	8.4yrs	LNG is a Product.	140 years hard coal -260 including sub-bituminous coal
Expected world peak production	Est. Peak 2005-2020, non-OPEC first	Natural gas liquids expected to peak in 2027, deep water in 2014, and polar in 2030	Production limited but increasing; heavy dependence; will not peak for decades, production in 2050 expected to be about 5GB/yr	Est. 138,500 billion metric ton of oil	Estimated peak of Production is 2030-2035	Est. Peak 2025	Est. Peak 2050
Current world stock	930-1300 gb	200gb	Est. 170gb from tar sands in Alberta, Canada; est. 27 GB extra-heavy crude in Orinoco, Venezuela	992gb	6204 tcf proved reserves (bp world statistics)	Lng is a product	26,578 qbtu (1,102,587 million tons)
World Proved Reserve Lifetime (No increased demand)	37-52 years	55yrs	999 years	Unknown	65 years	27yrs	255 years
World Proved Reserve Lifetime (projected demand increases)	28-37 years if 2.1% increase	Na	Na	Na	39 years if 2.5%/yr increase		109 years if 1.4%/yr increase
Environmental impact	Production of greenhouse gases, NOx, and CO, drilling and production leads to local pollution.	Production of greenhouse gases, NOx, and CO, drilling and production leads to local pollution.	Production from tar sands results in significant waste, consumes other energy due to the steam required for extraction, and pollutes watersheds.	Large quantities of contaminated water, sulfur, asphalt, and bitumen contaminated sand	Production of ghgs, nox, and CO, drilling and production leads to local pollution. Exploitation of now restricted areas lead to environmental damage.	Same impact as NG when combusted. Terrorist targets. Shipping impacts.	Most environmentally damaging fossil fuel, ghgs, nox, CO, sox, and PM when burned, mining leads to significant local damage.
Applications	97% of transportation industry, to a lesser degree for heating and power generation, chemical	Same as conventional oil.	Same as conventional oil.	Industrial combustion and petrochemical feedstock.	Combustion processes, petrochemical feedstock, could be expanded into a transportation fuel.	Same applications as natural gas, flexible and readily usable fuel.	90% of u.s. coal consumption is in power production.
Technology issues	Except for the Mideast, cheap oil is becoming hard to find. Technology for deep offshore and polar exploration needs to continue to develop.	Expensive to harvest deepwater as depth increases. New technology breakthroughs required.	More energy efficient and environmentally benign extraction technologies required.	Oil shale not currently viable for extraction.	Deep water, polar, in-situ liquefaction all need more research and development.	LNG production facilities have 7yr lead time, LNG ships are potential security threats, LNG terminals need to be constructed.	IGCC technology needed. Polygeneration to liquid crude petroleum currently too costly. R&D thrust.
Investment needs/ limiting factors	Worldwide oil investment required to 2030 is about $3T.	See conventional oil	See conventional Oil	R&D to make process more efficient and environmentally acceptable.	$40B/yr in U.S. for exploration $2.5B/yr in U.S. for transmission pipeline from AK, worldwide investment to 2030 is about $2.7T	Infrastructure needs to be expanded. About $250B in the Middle East is required to built production facilities. See natural gas investment.	R&D in clean combustion and carbon sequestration required. Worldwide investment required to 2030 is approximately $400B.

Table 3. Energy options (Cont'd).

Nuclear Power	Renewables								Grid
Nuclear Power	Ethanol	Hydrogen	Biomass	Solar	Wind	Hydroelectricity	Geothermal	Conservation	Electrical System
$33-41/MWh (Uranium costs approx $10/lb U3O8)	About 3 times the price of gasoline.	On a large scale equal to gasoline at the refinery.	$20-40/ton	Electric: 24-48 cents/kWh	3-5 cents/kWh	2.4-7.7 cents/kWh	Cost varies depending on technology.	Cost varies depending on technology.	U.S. average 7.5 cents/kWh
Fairly stable electrical prices. Uranium market has been volatile over the past decade.	Will remain stable unless new technology using cellulosic biomass is perfected, then price will drop.	Highly dependent on technology and transportation issues.	Stable, but somewhat dependent on transportation costs.	Price reduces 20% for every doubling of production.	Price reduces with increased production of turbines and larger turbine sizes.	Very few sites being developed. Price is stable.	NA	Decreasing over time.	Slow growth over time.
32,600 tU in 1999.	3.3 Bgal (U.S. only)	50 million tons	50 EJ/yr (2000) Biomas is not a world commodity,	0.2 Exajoules/yr (2000)	0.2 Exajoules/yr (2000)	10 Exajoules/yr (2000)	57TWh (2002)	NA	13,920 Billion kWh
In the United States, existing plants are being uprated, 2-3 new plants are in the planning stages, demand could grow significantly if carbon dioxide production becomes regulated or taxed.	Demand expected to grow as MBTE is banned in more states and may be banned in U.S. Another 750MGal of capacity under construction. Worldwide it is expected to quadruple over the next 25 yrs.	The demand depends on technology development and the ability to create from sources other than fossil fuels. Increasing demand expected next 10-15 yr.	DOE projects low growth rate, although state renewable portfolio requirements may spur growth	Continues to expand. Production of Solar Electric PV by 2030 expected to be 98 TWh. Solar thermal electric expected to be 21 TWh by 2030.	Fastest growing energy resource. In 2005 it is expected that 2500 MW will be deployed.	High head hydro has peaked in U.S.; all likely sites have been used. New sites controversial in other countries due to environmental impact. Low growth expected.	Production expected to triple by 2030. Will be developed where available, not a world or national market.	Efficiency cost is reducing over time while energy costs are increasing. More demand for conservation expected.	Worldwide expected to double by 2030. U.S. growth expected to grow about 2%/yr.
No air pollution, no GHG emissions, limited import dependence (just source fuel) high reliability, lowest fuel costs, least sensitive to fuel costs	Made from a renewable resource, low emissions, carbon neutral.	Clean burning.	Carbon neutral, renewable resource.	Carbon neutral, renewable resource.	Carbon neutral, renewable resource	Carbon neutral, renewable resource.	Carbon neutral, renewable resource, continuously available 24/7.	Carbon neutral, renewable resource, continuously available 24/7.	Extremely flexible high end commodity.
Plant construction costs $5k/kW (Watts Bar - last one built), extended construction times for new plants, fuel cycle not closed, no spent fuel disposal method at this time, great public fear and resistance to new facilities.	Low return on energy invested to produce, lower specify energy density than gasoline	Derived from fossil fuels, usually NG. Low specific energy density. Leakage problems for pipeline usage.	Should be used near where produces to avoid high shipping costs, low specific energy density compared to fossil fuels.	High cost, still needs considerable R&D and market penetration. Solar access required. Intermittent resource.	Limited sites in areas of high population density. Intermittent resource.	High head applications destroy aquatic systems.	Regional resource, not generally available, mostly in the Western U.S.	None, best path to follow.	Extremely inefficient electric production and distribution paradigm.
104 licensed generating plants = 97.4GW.	Production increasing as demand increases to replace MBTE.	11 Million tons/yr	512 MTon dry of biomass equivalent to 8.09QBtu of primary energy could be available at < $50/dry [illegible]	NA	10,777 TWh	High head almost fully exploited. Low head potential is about 21,000 MW	Regional resource, not generally available, mostly in the Western U.S.	20-40% of existing and future usage.	System meets demands with isolated problems.
14 yrs	NA	NA	Renewable	Renewable	Renewable	Renewable	Renewable	NA	NA
NA	NA	NA	>250 EJ/yr	>1600 EJ/yr	600 EJ/yr	50 EJ/yr	>250 EJ/yr	NA	NA
0.92 MtU at $15/lbU3O8 (2.96 MtU at $50/lbU3O8).	NA	NA	50 EJ/yr	0.2 EJ/yr	0.2 EJ/yr	10 EJ/yr	2 EJ/yr	NA	NA
10 yrs at low price-33yrs at high price	NA		Renewable	Renewable	Renewable	Renewable	Renewable	NA	NA
10-20 years	NA	NA	Renewable	Renewable	Renewable	Renewable	Renewable	NA	NA
Power plants have large thermal signature. Waste disposal unresolved. Accidents could spread fission products over a large area leading to cancer deaths and unusable land areas.	Ethanol is a by-product of agriculture and has the same agricultural impacts, combustion emissions.	Very benign.	Direct combustion results in CO, NOx, and Particulates. Harvesting and transportation has impacts depending on type and source.	Land consumption. Hazardous waste in production. Some deaths mostly associated with falls from roofs, etc.	Bird kills, noise, visual pollution, and land consumption.	Large dams completely change river hydrology, water temperature, and flood large riparian areas. Low head hydro much more benign and can use run of river.	Some sulfur emissions, significantly less impact that fossil fuels.	None	Electromagnetic radiation, transmission lines, and power plant impacts.
Production of electricity, has potential for production of hydrogen and district heating.	Automobile fuel as a substitute for MBTE or as a motor fuel E85.	Fuel cells	Electric generation and heat source.	Solar thermal and solar electric	Electric Power	Electric Power	Electric Power and thermal loads.	Throughout economy.	Throughout economy.
New, safe reactor designs. Waste disposal unresolved issue. New licensing process underway.	High cost. Low net energy. Cellulose and hemicellulose technology needed to increase feedstock and lower costs.	Carbon fiber storage tanks for compressed H2 could be breakthrough technology.	Continued research on gasification and liquefaction.	Photovoltaics too expensive. Efficiency must be higher and collector costs must be lower.	Turbines continue to increase in size and economies of scale still in effect.	Well developed technology. Fish friendly turbines needed.	Well developed, source constrained.	Somewhat of a market failure, although cost decreasing. Needs more emphasis as national strategy.	Some congestion on grid. Building new infrastructure problematical.
Waste disposal unresolved, closing the fuel cycle unresolved, R&D in breeder reactors and fusion power.	Ethical concern with using food quality starch as feedstock.	R&D on H2 sources, storage, and distribution	R&D on gasification.	R&D in energy storage	Good wind sites are far from population centers.	Most sites for high head used. Environmental factors will prevent further development in OECD countries.	Availability of sites.		$10T worldwide by 2030.

Coal Trends

Coal is the nation's largest fossil fuel resource with a 250-year supply at current consumption rates. Despite the large production of CO_2 and other air pollutants generated by coal consumption, the utility sector and, possibly the large industrial sector will continue to increase their use the nation's large supplies of coal. Using current technologies, coal combustion remains problematic, but research shows some promising technological solutions. Deploying poly-generation techniques with carbon sequestration on a large scale may potentially allow the United States to use the nation's coal reserves in an environmentally friendly way to meet both liquid fuel and electricity requirements. Carbon sequestration technologies will begin to play a larger role in the mid-term. However, carbon sequestration techniques must be well thought-out to avoid unintended consequences to the ecosystem such as unexpected large releases of carbon into the environment.

Nuclear Power Trends

Nuclear power appears headed for a small renaissance. Some nuclear plant upgrades are planned in the short term. In the mid term, a modest construction program is getting under way and some shut-down reactors may be restarted. Light water reactors, for which the United States imports much of its nuclear fuel, are only an interim technology. Developing a breeder reactor program and closing the fuel cycle could offer true energy independence, but at the cost of increased environmental and security risks. It remains to be seen if this is a viable solution from both political and ecological perspectives. Other nations such as France and Japan have closed the fuel cycle and are taking an energy path with a much higher nuclear profile.

Renewable Energy Trends

Renewable energy technologies will certainly be a growing part of the energy mix and will penetrate faster and further than conventional energy advocates think. Early adoption to promote this market and these technologies is inherently in the Army's interest. From an economic perspective, the cost of renewable technologies continues to fall while the cost of conventional energy sources continues to rise.

Electrical System Trends

The electrical system will likely become increasingly problematic over the next 5 to 10 years. Power capacity should suffice. Utilities have overbuilt to meet the peaking market and are planning additions to base capacity. The grid, itself, however is the weak point in the Nation's electrical system. Investments are not keeping up with power flow demands; consequently, bottlenecks exist in certain regions, which lowers the reliability of the grid as a whole. Once ongoing regulation and deregulation activities are settled, appropriate investments can achieve grid expansions and upgrades. The fraudulent electrical pricing and supply manipulations by commodity traders that led to the California energy crisis in 2001 should not recur.

Energy Options

Energy consumption is indispensable to our standard of living, and necessary for the Army to carry out its mission. However, current trends are not sustainable. The impact of excessive, unsustainable energy consumption may undermine the very culture and activities it supports. There is no perfect energy source; all are used at a cost. Table 3 lists energy options and their associated features, including applications, advantages, disadvantages and projected reserve lifetimes.

Energy Implications for Army Installations

The days of inexpensive, convenient, abundant energy sources are quickly drawing to a close. Domestic natural gas production peaked in 1973. The proved domestic reserve lifetime for natural gas at current consumption rates is about 8.4 yrs. The proved world reserve lifetime for natural gas is about 40 years, but will follow a traditional rise to a peak and then a rapid decline. Domestic oil production peaked in 1970 and continues to decline. Proved domestic reserve lifetime for oil is about 3.4 yrs.

World oil production is at or near its peak and current world demand exceeds the supply. Saudi Arabia is considered the bellwether nation for oil production and has not increased production since April 2003. After peak production, supply no longer meets demand, and prices and competition increase. The proved reserve lifetime for world oil is about 41 years, most of this at a declining availability. Our current throw-away nuclear cycle will consume the world reserve of low-cost uranium in about 20 years. Unless we dramatically change our consumption practices, the Earth's finite resources of petroleum and natural gas will become depleted in this century. Coal supplies may last into the next century depending on technology and consumption trends as it starts to replace oil and natural gas.

We must act now to develop the technology and infrastructure necessary to transition to other energy sources and energy efficient technologies. Policy changes, leap-ahead technology breakthroughs, cultural changes, and significant investment is requisite for this new energy future. Time is essential to enact these changes. The process should begin now.

Our best options for meeting future energy requirements are energy efficiency and renewable sources. Energy efficiency is the least expensive, most readily available, and environmentally friendly way to stretch our current energy supplies. This ensures that we get the most benefit from every Btu used. It involves optimizing operations and controls to minimize waste and infusing state of the art technology and techniques where appropriate. The potential savings for the Army is about 30 percent of current and future consumption. Energy efficiency measures usually pay for themselves over the life cycle of the application, even when only face value costs are considered.

Renewable options make use of the Earth's resources that are not depleted by our energy consumption practices: namely solar, wind, geothermal, geoexchange, hydrology, tidal movements, agricultural products, and municipal wastes. Renewable options also make use of the large stretches of land in America, much of which is owned by the government. These options are available, sustainable, and secure. The affordability of renewable technologies is improving steadily. If the market is pulled by large Army applications, cost reductions could be dramatic. For efficiency and renewables, the intangible and hard-to-quantify benefits (e.g., reduced pollution and increased security) yield indisputable economic value.

Many of the issues in the energy arena are outside the control of the Army. Several actions are in the purview of the national government to foster the ability of all groups, including the Army, to optimize their natural resource management. The Army needs to present its perspective to higher authorities and to be prepared to proceed regardless of the national measures that are taken. Steps by the national government that would help the Army with its energy challenges include the increase of supplies, the modernization of infrastructure, the diversification of sources, the optimization of end-use, the minimization of environmental impact, and the cooperation in global energy markets.

In these times of tightening traditional energy options, the Army needs to take steps comparable to those in the national agenda mentioned above, in addition to pulling technology markets, cooperating in regional purchases, and leveraging alternate financing. Special attention to the diversification of sources is appropriate. This incorporates a massive expansion in renewable energy purchases, a vast increase in renewable distributed generation including photovoltaic, solar thermal, wind, microturbines and biomass, and the large-scale networking of on-site generation.

The awareness of the energy options, trends, tradeoffs and the implications for Army installations allows for informed decisions, targeted planning, and pertinent investment. The Army must continue to improve and optimize its energy and water management to meet mission requirements.

Information in this Technical Note is expanded in ERDC/CERL TR-05-21, *Energy Trends and their implications for U.S. Army Installations*, which is accessible through the World Wide Web (WWW) at URL:

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